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Urban heat: an increasing threat to global health

Shilu Tong and colleagues describe the health consequences of extreme urban heat and the priorities for action and research to mitigate the harms

Cities are a crucial concern in dealing with climate change because an increasing proportion of the global population lives in urban areas. The world's urban population is expected to grow from 4.2 billion in 2018 to 6.7 billion by 2050, including a burgeoning ageing population.¹ Meanwhile, because of human induced climate change, the frequency of extreme climate events is increasing worldwide.² Climate change, urbanisation, and an ageing population create a "perfect storm" of risks to global health, particularly from urban heat.

If we do nothing, current temperature extremes are projected to be exceeded across much of the Earth by 2100.³ The more extreme that heat events are, the greater the potential to push ecosystems and communities beyond their ability to cope.^{2 4} Whether we can achieve sustainable development depends on our actions now and over the next few years. As heat related health risks are particularly severe in cities, it is imperative to assess these risks and respond effectively.

Health consequences of heat exposure

Anthropogenic emissions of greenhouse gases are altering our climate system, and more frequent and intense heat related disasters such as heatwaves, droughts, and wildfires have already led to increased mortality and morbidity.^{2 4 5} For example,

the number of excess deaths during the 2003 heatwave in Europe was estimated to be 70 000, including around 15 000 people in France alone.⁶ The 2018 Japan heatwaves resulted in over 20 000 hospital admissions related to heat stroke, mostly in people aged 65 years or older.⁷

Raised ozone levels due to higher temperatures and air pollutants from burning fossil fuels also increase cardiorespiratory mortality and morbidity, possibly by increasing cholesterol levels and systemic inflammation.^{8 9} Rising incidence of kidney disease and mental illness associated with exposure to urban heat are other devastating effects.^{2 4 5} Additionally, increasing urban heat is expected to reduce labour productivity and outdoor working capacity, particularly in the tropics and subtropics. The health effects of extreme heat events have the potential to overwhelm health systems, which in turn may have further negative health consequences, particularly in developing countries.⁷

The nature and magnitude of health risks depends on the hazards created by a changing climate, and the exposure and sensitivity of individuals and communities. For instance, an international study examined the effects of greenhouse gas emissions, population growth, and adaptation on heatwave related mortality.¹⁰ Compared with 1971–2020, the predicted rise in mortality in 2031–80 varied from 2000% in Colombia to 150% in Moldova under the highest emissions and high variant population scenario, without any adaptation. For a lower emissions scenario and adaptation, the mortality increase would be much smaller.

Urban heat islands

Urban areas are generally warmer than adjacent rural and suburban areas (fig 1). This phenomenon is known as the urban heat island effect.¹¹ For example, while the average air temperature in the centre of a large city like London, can be 4°C higher than outer rural areas, this differential can reach 10°C during extreme heat events, with the largest differential at night.^{12 13} Urban heat islands are caused by use of materials such as metal, concrete, and brick

that are highly efficient at absorbing and storing heat from the sun, a lack of vegetation limiting the cooling effect of evaporation from the soil and plant transpiration (evapotranspiration), and trapping of heat released by human activities (eg, transport, lighting, air conditioning) in "urban street canyons."¹⁴

Urban heat islands can affect health directly and indirectly.¹⁵ Studies have found that the increased heat has a direct effect on mortality and morbidity, particularly during extreme heat events.^{16 17} One study reported that the heat island effect accounted for over 50% of the total heat related mortality in the West Midlands, UK, during the 2003 heatwave.¹⁸ Another study indicated that vulnerable populations (such as elderly people and those on low incomes) are often concentrated in areas where the heat island effect is highest.¹⁹ Urban heat islands can also affect rainfall patterns and worsen air pollution, exacerbating health harms.^{20 21} Furthermore, climate change and the urban heat island effect are co-evolving factors that could amplify future heat effects.^{22 23} By 2100, heat related mortality in Europe is expected to increase by about 50 times because of climate change augmented by urban expansion.²²

Vulnerability to urban heat

A recent study indicates that increased exposure to extreme heat from both climate change and the urban heat island effect threatens rapidly growing urban settlements worldwide.²⁴ It estimated the daily population exposure to extreme heat for 13 115 urban settlements from 1983 to 2016 and found that global exposure to extreme heat (defined as a daily maximum wet bulb globe temperature threshold of 30°C) increased nearly 200% during the study period.²⁵

However, vulnerability to heat is not equal for all city residents.^{24 26 27} Risk is increased by degree of exposure to heat (eg, living in heat island neighbourhoods, lack of tree cover, lack of air conditioning, living on upper floors of buildings, and working outdoors), susceptibility (young and old people and those with low education attainment, ill health, or lacking adequate healthcare), social isolation, and a lack

KEY MESSAGES

- Urban heat is one of the most serious health hazards created by climate change
- Effects of urban heat include increased mortality and morbidity from cardio-pulmonary diseases, kidney disease, and mental illness
- Health risks related to urban heat are likely to intensify over the coming decade, as climate change proceeds and urbanisation increases
- Changes to building and city design as well as wider climate action are urgently required to cope with and prevent the harms of extreme heat

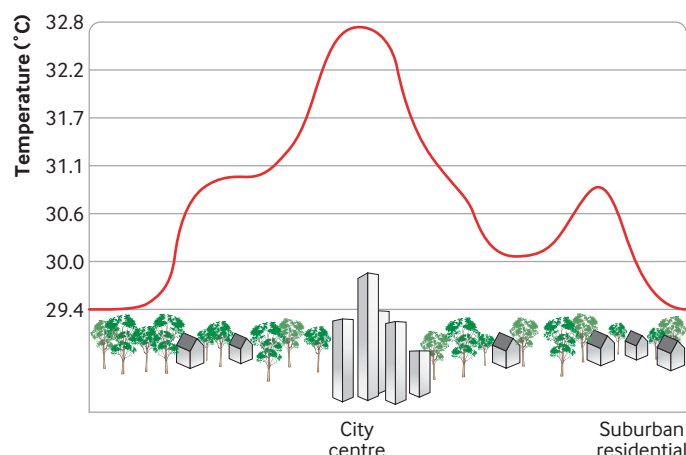


Fig 1 | Schematic profile of urban heat island effect

of material resources.²⁸ Understanding which individuals and neighbourhoods are most vulnerable can help guide local adaptation efforts. Vulnerability maps enable health officials and policy makers to identify “hotspots” within cities and target interventions to places and people most in need.^{29–31}

We urgently need to evaluate the effect of urban characteristics on temperature–health relationships because urban populations experience higher heat risks, particularly in a warming climate. An international study found that the effects of heat on mortality were higher in cities with a higher level of inequality, higher exposure to air pollution, fewer green spaces, and lower availability of health services.³² These findings can inform public health interventions and urban planning.

Managing urban heat

The health risks of heat can be mitigated by reducing the accumulation of heat and applying cooling techniques. Possible strategies include altering individual behaviours, improving building design and city planning, and developing heat health warning systems.

At the individual level, light clothing, water sprays, and cool showers can help.³³ Although air conditioning can reduce mortality and morbidity, it can exacerbate the urban heat island effect by dissipating heat outdoors. It is also often unavailable to vulnerable populations, and can be unreliable if power outages occur during hot days.¹³ Structural adaptation is therefore needed.

Four general principles have been identified to guide building and city design to reduce the heat island effect (box 1).³⁴ Table 1 lists some measures that can be used to implement these principles.³⁵

Surface reflectivity (albedo) in urban areas is one of the most important determinants of the magnitude of the heat island effect. Increasing reflectivity, for example by painting surfaces white, can reduce urban air temperatures by 1–3.5°C.³⁶ One study found that in combination, increasing the albedo and the vegetated area can lead to a 48% reduction in annual emergency service calls.³⁷ Another study reported that this combination could offset 40–99% of the projected increase in heat related mortality arising from climate change.³⁸

Urban greening as a heat mitigation strategy, including urban forests, parks, and green walls, has received much attention.^{39–40} Through enhancing evapotranspiration rates and shading, greening can achieve localised cooling within 2–3 m from the surface.^{41–42} The cooling effect of green roofs is less as they are above street level.⁴³

Urban design will not eliminate the dangers from extreme heat events. Heat health warning systems have thus emerged as a key tool for managing urban heat risk,⁴⁴ as they can warn authorities tasked with

intervention strategies about impending heat hazard.^{45–46} Use of heat health warning systems in Philadelphia, US, and Shanghai, China, has been associated with lower mortality rates.^{46–47} Alerts need to be linked to heat-health action plans that activate response measures (eg, opening cooling centres, potable water stations, outreach to vulnerable populations) and heat related health education.⁴⁸

Although developed countries are able to use a range of approaches to manage urban heat, options are potentially limited in developing countries,^{49–50} and the benefits of adaptation strategies may be moderated by socioeconomic and cultural factors.⁵¹ Raising awareness of how heat affects different groups, targeting high risk communities, and more inclusive planning processes may help improve equity.

Going further

Although cities have been centres of innovation and growth, and the engines of socioeconomic development, urban dwellers are vulnerable to the combined effects of urban heat islands and increasing heat from climate change.⁵² Children born in 2020 will experience a twofold to sevenfold increase in extreme events, particularly heat waves, compared with people born in 1960, under current climate policy pledges.⁵³ This highlights the severe threat to young generations and calls for drastic emission reductions to safeguard their future. Research and policies need to focus on increasing climate ambition, curbing emissions, building resilience, and advancing science.

Increasing climate ambition

Climate change is the biggest threat facing humanity over the long run, although the covid-19 pandemic is currently the most urgent crisis. Mitigating climate heating by reducing greenhouse gas emissions

Box 1: How to minimise heat harms when building cities*

- *Efficiency of urban systems*—Urban waste heat and greenhouse gas emissions from infrastructure (including buildings and transportation) and industry can be reduced through improvements in the efficiency of urban systems
- *Form and layout*—Modifying the form and layout of buildings and urban districts can provide cooling and ventilation that reduces energy use and allow citizens to cope with higher temperatures and more intense run-off
- *Heat resistant construction materials*—Selecting low heat capacity construction materials and reflective coatings can improve building performance by managing heat exchange at the surface
- *Vegetative cover*—Increasing the vegetative cover in a city can simultaneously lower outdoor temperatures, demand for building cooling, run-off, and pollution while sequestering carbon

*Adapted from Raven et al³⁴

Table 1 | Heat adaptation options, evaluations indices, and effects³⁵

Adaptation option	Evaluation index	Main climate effect
Green shade and solar transmittance	Evaporative efficiency, sun shade	Evaporative cooling
Solar radiation shade and transmittance	Convection heat transfer coefficient	Sun shade, convective heat transfer
Retroreflective surface	Downward solar reflectance	Solar reflection
Water retentive pavement	Evaporative efficiency	Evaporative cooling
Cool pavement	Solar reflectance	Solar reflection
Green pavement	Evaporative efficiency	Evaporative cooling
Green wall	Evaporative efficiency	Evaporative cooling
Water retentive wall	Evaporative efficiency	Evaporative cooling
Fine mist spray	Evaporation rate	Evaporative cooling
Awning	Solar transmittance	Sun shade
Fractal shaped sunshade	Solar transmittance, convection heat transfer coefficient	Sun shade, convection heat transfer
Mesh shade and water supply	Solar transmittance, evaporative efficiency,	Sun shade, evaporative cooling
Evaporative cooling louvre	Evaporative efficiency	Evaporative cooling
Greening cooling louvre	Evaporative efficiency	Evaporative cooling
Tree pot	Solar transmittance, evaporative efficiency	Sun shade, evaporative cooling
Water retentive block	Evaporative efficiency	Evaporative cooling
Water surface	Evaporative efficiency	Evaporative cooling
Fine mist spray with blower	Evaporation rate	Evaporative cooling
Ceiling cooling system	Surface temperature	Artificial cooling
Water cooling bench	Surface temperature	Artificial cooling
Water surface	Evaporative efficiency	Evaporative cooling
Watering	Evaporative efficiency	Evaporative cooling
Fine mist spray	Evaporation rate	Evaporative cooling
Shading	Solar transmittance	Sun shade
Tree planting	Solar transmittance, evaporative efficiency	Sun shade, evaporative cooling
Roof and ground greening	Evaporative efficiency	Evaporative cooling
Wind and ventilation	Convection heat transfer coefficient	Convective heat transfer
Traffic mode control	Anthropogenic heat release	Reduction of anthropogenic heat release
Unused energy use and natural energy use	Anthropogenic heat release	Reduction of anthropogenic heat release
Information and communication technology use	Human body physiological amount	Reduction of human thermal load

is a public health priority.⁵⁴ All nations need to boost their climate ambition, and its momentum should be monitored and enhanced through each country agreeing their nationally determined contributions to reducing emissions this year. The Paris Agreement requires countries to set out plans for reaching nationally determined contributions every five years, and these are legally binding commitments.⁵⁵

Curbing emissions

The Paris Agreement set a goal to limit warming to 1.5–2°C above pre-industrial levels. Regrettably, climate action has since stalled, making drastic reduction in greenhouse gas emissions imperative. Climate change will shift temperature distribution, both the extremes and the mean, towards a warmer world and increased heat health risks. Swift and decisive actions are needed to mitigate urban heat and protect population health.

Better communication channels between government agencies, research organisations, non-governmental organisations, and the general public should be developed. Scientists and policy makers must collaborate in projects to answer specific policy oriented research questions. Climate related health issues are a matter for all government departments,

and the concept of “health for all” should be embraced in decision making processes in the environment, urban planning, energy, transport, and public health sectors.

Building resilience

The United Nations 2030 Agenda for Sustainable Development and the Paris Agreement aim to achieve a resilient, equitable, and prosperous future for all.⁵⁶ Policy makers may have less time to respond to climate effects than previously thought, given the recent acceleration of climate change.⁵⁷ If we continue as we are today, by 2100, many cities will experience average temperatures that are 4–7°C higher in the hottest months, relative to 1988–2017.⁵² All cities need adaptation plans (including climate sensitive urban design, heat health warning systems, and heat action plans) to reduce and prevent the harms of urban heat.

In light of the covid-19 pandemic, cities should rethink their strategies for protecting residents during heat events. For example, what is the role of cooling centres when social distancing is necessary? Surveillance of heat related health risks needs to be strengthened. Long term surveillance data are critical for estimating the health consequences of heat

exposure and evaluating the effectiveness of adaptation strategies. Implementation studies should be conducted to identify the best adaptation strategies. For example, the use of air conditioners can reduce heat stress but increases greenhouse gas emissions, and there may be better ways to handle extreme heat. Reducing heat related health inequalities within urban areas should also be part of future urban policy.

Advancing science

The scientific community needs to advance the science of urban heat and engage government and the public in doing so. Transdisciplinary and cross-sectoral collaboration is required to reduce uncertainties in decision making and evaluate the effectiveness of adaptation and mitigation strategies. Funders need to increase their investment in transdisciplinary and collaborative research to better understand the health risks of heat exposure and related climate action priorities.

Act now

Worldwide, extreme heat exposure will be particularly pronounced in cities. Climate change, population ageing, increasing urbanisation, and widening inequalities, place urban residents at increased risk of

overheating, with a disproportionate effect on vulnerable groups.

We urgently need to stabilise the climate by reducing greenhouse gas emissions and adapt to those aspects of climate change that cannot be avoided. Climate action is imperative because climate change is already affecting our health, and the harms will increase over time. Medical professionals and urban policy makers have a key role in endeavours to mitigate the harms of heat, supported by robust science. Let's act fast and decisively.

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Contributors and sources: ST is an epidemiologist who has researched and written extensively on health risks of climate change. JP has studied and reported widely on urban health issues and has a long research interest in the role of urban planning and design in promoting healthy communities. GM is a climatologist with expertise in the assessment of heatwave related health outcomes. XS is an environmental epidemiologist who has researched and reported on risk assessment of environmental exposures and health benefits of environmental quality improvements. PK has studied and reported on the health effects of air pollution and climate change, and the health benefits of policies to address these challenges. ST conceptualised and designed the analysis. He wrote the first draft, with substantial input from JP, GM, XS, and PK. All authors approved the final version. ST is guarantor for the paper.

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